

A decade of web server updates at the bioinformatics links directory: 2003–2012

Michelle D. Brazas¹, David Yim¹, Winston Yeung¹ and B. F. Francis Ouellette^{1,2,*}

¹Ontario Institute for Cancer Research, 101 College St., Suite 800, Toronto, Ontario, Canada M5G 0A3 and

²Department of Cell and Systems Biology, 25 Harbord Street, University of Toronto, Toronto, Ontario, Canada M5S 3G5

Received May 28, 2012; Revised June 4, 2012; Accepted June 5, 2012

ABSTRACT

The 2012 Bioinformatics Links Directory update marks the 10th special Web Server issue from *Nucleic Acids Research*. Beginning with content from their 2003 publication, the Bioinformatics Links Directory in collaboration with *Nucleic Acids Research* has compiled and published a comprehensive list of freely accessible, online tools, databases and resource materials for the bioinformatics and life science research communities. The past decade has exhibited significant growth and change in the types of tools, databases and resources being put forth, reflecting both technology changes and the nature of research over that time. With the addition of 90 web server tools and 12 updates from the July 2012 Web Server issue of *Nucleic Acids Research*, the Bioinformatics Links Directory at http://bioinformatics.ca/links_directory/ now contains an impressive 134 resources, 455 databases and 1205 web server tools, mirroring the continued activity and efforts of our field.

COMMENTARY

'Because the number of artifacts has increased greatly, it is impossible for many bioinformatics researchers to track tools, databases, and methods in the field—or even perhaps within their own specialty area. More critically, however, biologist users and scientists approaching the field do not have a comprehensive index of bioinformatics algorithms, databases, and literature annotated with information about their context and appropriate use.' (1)

The need to not only share bioinformatics databases, tools and resources but also compile a bioinformatics 'resourceome' has been evident for some time (1).

In dedicating a special issue each year since 1993 to new databases or updates and a second issue each year since 2003 to new web server tools or updates, *Nucleic Acids Research* has successfully created a viable and recognizable dissemination mechanism. Each year since 2005 and extending back to 2003, the Bioinformatics Links Directory has coordinated with *Nucleic Acids Research* (*NAR*) to update their community driven 'resourceome' with all of *NAR*'s web server tools (2–8). This coordinated effort has resulted in a comprehensive public repository of bioinformatics tools and databases, annotated with contextual information and organized by functional relevance (http://bioinformatics.ca/links_directory). Users requiring a bioinformatics tool or database for their research may search the Bioinformatics Links Directory using any number of its features, from browsing the biological categories and their drop-down subcategories on the main page, to computing a keyword search from the search box or selecting related links. Content within the Directory is organized by biological subject, with subcategories of common tasks relevant to each subject listed under the corresponding category (Figure 1). A keyword search from the search box (Figure 2) returns links containing the entered keywords found within either the link's title, description or tag terms—a search for 'gene set enrichment' for example returns links containing a Boolean combination of gene AND set AND enrichment, with these keywords highlighted in yellow where they appear in the returned list (Figure 3). Other specific searches may also be computed such as exact word matches using quotation marks. Returned links from a given search may be refined to one or more of the link types within the Links Directory (tools, resources or databases), using the 'Search Options' feature (Figure 4). From a link of interest, related or similar links within the Links Directory are retrievable by selecting the 'Related Links' tab, where related links are chosen based on the PubMed-related citations feature for the primary

*To whom correspondence should be addressed. Tel: +1 416 673 8511; Fax: +1 416 977 7446; Email: francis@oicr.on.ca

© The Author(s) 2012. Published by Oxford University Press.

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

bioinformatics.ca
links directory

Bioinformatics Links Directory

🔍
Search Bioinformatics Links Directory
Search Directory

Bioinformatics Links Directory

The Bioinformatics Links Directory features curated links to molecular resources, tools and databases. The links listed in this directory are selected on the basis of recommendations from bioinformatics experts in the field. We also rely on input from our community of bioinformatics users for suggestions. Starting in 2003, we have also started listing all links contained in the NAR Webserver issue.

Computer Related (70)

This category contains links to resources relating to programming languages often used in bioinformatics. Other tools of the trade, such as web development and database resources, are also included here.

DNA (447)

- [Annotations](#)
- [Databases](#)
- [DNA and Genomic Analysis](#)
- [Gene Prediction](#)
- [Mapping and Assembly](#)
- [Phylogeny Reconstruction](#)
- [Sequence Polymorphisms](#)
- [Sequence Retrieval and Submission](#)
- [Structure and Sequence Feature Detection](#)
- [Tools For the Bench](#)

... more

Education (61)

Links to information about the techniques, materials, people, places, and events of the greater bioinformatics community. Included are current news headlines, literature sources, educational material and links to bioinformatics courses and workshops.

... more

Figure 1. The homepage of the Bioinformatics Links Directory displays the functional categories and subcategories within which more than 1700 tools, resources and databases are contained. The DNA category is shown expanded into its subcategories.

link. To aid with determining the usefulness and currency of a link, all links within the Links Directory with one or more citations have a per PubMed Identifier (PMID) and cumulative Google Scholar (9) citation count, as well as a Google+ and Twitter sharing count (10) (Figure 5). A keyword search will return links in descending order of cumulative citation count. Detailed explanations and examples of searching within the Links Directory are provided on the tutorials page at http://www.bioinformatics.ca/links_directory/tutorial. These annotations and search features provide the ‘biologist user with information about a link’s context’ and usefulness so to narrow down the algorithm or database within the Bioinformatics Links Directory ‘resourceome’ best suited to their research need (1).

SHIFTING TRENDS

The past decade of *NAR* Web Server releases has seen significant growth and change in the types of tools, databases and resources being put forth. Although each Web Server issue has seen a steady number of new web servers and updates, the functional utility classification of these web servers has differed greatly over the decade. The Bioinformatics Links Directory in 2006 compiled a graph highlighting the trends in five subcategories of links published by *NAR* between 2003 and 2006 (3). An update of that graph (Figure 6) shows the exceptional changes in new bioinformatics web servers within these same selected subcategories; Table 1 lists how substantial these changes have been across the entire field of

Bioinformatics Links Directory

bioinformatics.ca
links directory

Search Bioinformatics Links Directory

- All search keyword are used in searching links:
e.g. *bioinformatics links directory* will search for links that contain *all* three keywords in title, description, or tags.
- You can search for an exact phrase by enclosing the query in quotes:
e.g. "*bioinformatics links directory*"
- e.g. Search query "*genomic sequences*" *dna* will search for links containing the phrase "*genomic sequences*" and *dna*.

Bioinformatics Links Directory

The Bioinformatics Links Directory features curated links to molecular resources, tools and databases. The links listed in this directory are selected on the basis of recommendations from bioinformatics experts in the field. We also rely on input from our community of bioinformatics users for suggestions. Starting in 2003, we have also started listing all links contained in the NAR Webserver issue.

Computer Related (70)	DNA (447)
This category contains links to resources relating to programming languages often used in bioinformatics. Other tools of the trade, such as web development and database resources, are also included here.	This category contains links to useful resources for DNA sequence analyses such as tools for comparative sequence analysis and sequence assembly. Links to programs for sequence manipulation, primer design, and sequence retrieval and submission are also listed here.

Figure 2. Searching for links within the Bioinformatics Links Directory may be done through use of keywords in the search box. Suggested search options are provided in the search guide box.

bioinformatics as well (Table 1). Subcategories with active contributions of new web servers in 2006 differ from the subcategories with active contributions of new web servers in 2012 (Figure 6 and Table 1). For example subcategories such as 'DNA: Tools for the Bench' subcategory, which contains new web servers for conducting generic DNA analyses such as primer design, exhibited strong growth over 2003–2006 but shows very little growth in 2012 as tools in this category remain relevant over time (Figure 6). In contrast, other subcategories such as Protein: 3D Structural Features have remained active in web server development over time, as the introduction of better technologies and algorithms has permitted a deeper appreciation of proteins and their structural features in 3D (Figure 6).

Indeed, many of these trends in subcategory activity reflect the introduction of a new research technology and/or an underlying research need. As originally discussed in 2009, yet still evident throughout Table 1, there are observable sharp spikes in the number of informatics tools available in a given biological area or specific to a particular task (6). Although between 2006 and 2007, there was a spike in 'DNA: Structure and Sequence Feature Detection', 'Expression: Gene Regulation' and 'Expression: Transcript Expression and Microarrays' most likely in response to the pervasive use of expression platforms and transcript analyses at that time, current

spikes in 'Human Genome: Genomics', 'Sequence Comparison: Comparative Genomics' and 'Sequence Comparison: Pairwise Sequence Alignments' between 2010 and 2012 may be reflective of the introduction of next-generation sequencing technologies. Table 1 highlights all the trends between 2005 and 2012 across all subcategories of the Bioinformatics Links Directory (Table 1) (individual calendar year data are not available for 2003–2005 as the Bioinformatics Links Directory collaboration with *NAR* began in 2005 for all data before that). Of note are the aggressive coverage of databases, which began in 2011 and the need for additional subcategories such as 'Other Molecules: Enzymes and Peptides' in response to the growing diversity and depth in the field.

CONSTANT GROWTH

The number of bioinformatics links produced by the community has nonetheless continued to accumulate over time. When first released in 2002 under Bioinformatics.ca, there were only 385 links in the database. By 2005, when the Bioinformatics Links Directory began its collaboration with *NAR*, the Directory already contained 700+ web servers and resources (2). The Bioinformatics Links Directory has

bioinformatics.ca
links directory

Bioinformatics Links Directory > Search for Links with keyword **gene set enrichment**

gene set enrichment

Search for Links with keyword **gene set enrichment**

Search Result RSS Compact View List as XML List as JSON

Found 6 matching categories

- DNA > **Gene Prediction** (30 links)
- Education > **General** (13 links)
- Expression > **Gene Regulation** (134 links)
- Expression > **Gene Set Analysis** (31 links)
- Model Organisms > **General Resources** (30 links)
- RNA > **General Resources** (10 links)

→ **SEARCH OPTIONS**

Found 7 links containing keywords **gene set enrichment**

Displaying 7 links

Babelomics

<http://www.babelomics.org> [OPEN IN A NEW WINDOW]

DNA > Annotations
Expression > Gene Regulation
Expression > Networks
Expression > Protein Expression
Expression > Transcript Expression Analysis
Expression > cDNA, EST, SAGE
Human Genome > Annotations
Protein > Networks & Interactions, Pathways and Enzymes

Babelomics is a suite of web tools for the functional annotation and analysis of groups of **genes** in high throughput experiments. Tools include: FatIGO, FatIGOplus, FatiScan, **Gene Set Enrichment** Analysis (GSEA), Marmite, and the Tissues Mining Tool (TMT). Other tools include Biocarta pathways, Transfac and a tool de novo functional annotation of sequences.

This content is being maintained by juan_aguilar.

PubMed CITATION COUNT: 1268

DOWNLOAD Download as XML Download as JSON

USER FEEDBACK

TAGS algorithms animals artificial intelligence binding sites
 chromosome mapping dna sequence analysis gene expression profiling genes
 genetic databases genomics humans mice
 oligonucleotide array sequence analysis phylogeny proteomics rats
 sequence alignment systems biology systems integration transcription factors

Figure 3. Keyword searches such as for gene set enrichment return matching categories and links, which contain the requested keywords highlighted in yellow.

bioinformatics.ca
links directory

Bioinformatics Links Directory > Search for Links with keyword *gene set analysis*

🔍 gene set analysis **Search Directory**

Search for Links with keyword *gene set analysis*

RSS [Search Result RSS](#)
 Compact View [Compact View](#)
 List as XML [List as XML](#)
 List as JSON [List as JSON](#)

Found 9 matching categories

- DNA > DNA and Genomic **Analysis** (28 links)
- DNA > **Gene Prediction** (30 links)
- Education > **General** (13 links)
- Expression > **Gene Regulation** (134 links)
- Expression > **Gene Set Analysis** (31 links)
- Expression > Transcript Expression **Analysis** (105 links)
- Model Organisms > **General Resources** (30 links)
- RNA > **General Resources** (10 links)
- Sequence Comparison > **Analysis of Aligned Sequences** (56 links)

SEARCH OPTIONS

You are refining search result for the search query 'gene set analysis'.

Restrict Link type:

Include 🔗 Resources in search results
 Include ☰ Databases in search results
 Include ⚙️ Tools in search results

You can search for links of specific type. If no link type is provided, all link types will be included.

SEARCH DISPLAY OPTIONS

Display 10 ▼ search results at any one time.

Search Links

Figure 4. A returned keyword search may be refined using the Search Options, where returned links may be refined to include or exclude all tools, resources and databases.

bioinformatics.ca
links directory

Bioinformatics Links Directory > Reactome

Search Bioinformatics Links Directory
Search Directory

View
Related Links

Reactome

<http://www.reactome.org> [OPEN IN A NEW WINDOW]

[Human Genome > Databases](#)
[Protein > Networks & Interactions, Pathways and Enzymes](#)

6
 2

Reactome is a database of human biological pathways and processes ranging from basic processes of metabolism to complex regulatory pathways. The data is curated by biologists and subsequently peer-reviewed for accuracy and consistency. Cross-references with UniProt, PubMed, Ensembl, Gene Ontology and LocusLink are also provided. Reactome supersedes The Genome Knowledgebase project.

Pub
LINKS DIRECTORY INDEX: 84

Title	Publication Year	Google Scholar Citation Count
The Reactome BioMart	2011	6
Reactome: a database of reactions, pathways and biological processes	2011	78

NAR Database Issue 2011

DOWNLOAD
 Download as XML
 Download as JSON

USER FEEDBACK

EXTERNAL LINKS
 [Link on Twitter](#)
 [Link on Wikipedia](#)

TAGS
 biological models
 biological processes
 factual databases

gene expression regulation
 genetic databases
 humans

metabolic networks and pathways
 protein databases
 signal transduction

Figure 5. All links within the Bioinformatics Links Directory now contain a per PMID and cumulative Google Scholar citation count for the citations listed for each link, as well as a Google+ and Twitter sharing count.

continued to grow (and diminish in size as web servers become extinct) with each successive year (Table 1). The Bioinformatics Links Directory now contains more than 1200 unique web servers. This year's *NAR* Web Server Issue introduces an additional 90 web servers and 12 server updates (Table 1). The complete listing of URLs cited in the 2012 Web Server Issue can be accessed online at the *Nucleic Acids Research* website, <http://nar.oxfordjournals.org/>,

and at http://bioinformatics.ca/links_directory/narweb2012/.

Growth has also resulted in change. In 2011, the Bioinformatics Links Directory introduced all the databases published by *Nucleic Acids Research* over their 2010–2011 window and completed a major reorganization of its existing links (8). Links were reclassified into one of three types reflecting the growing variety of bioinformatics

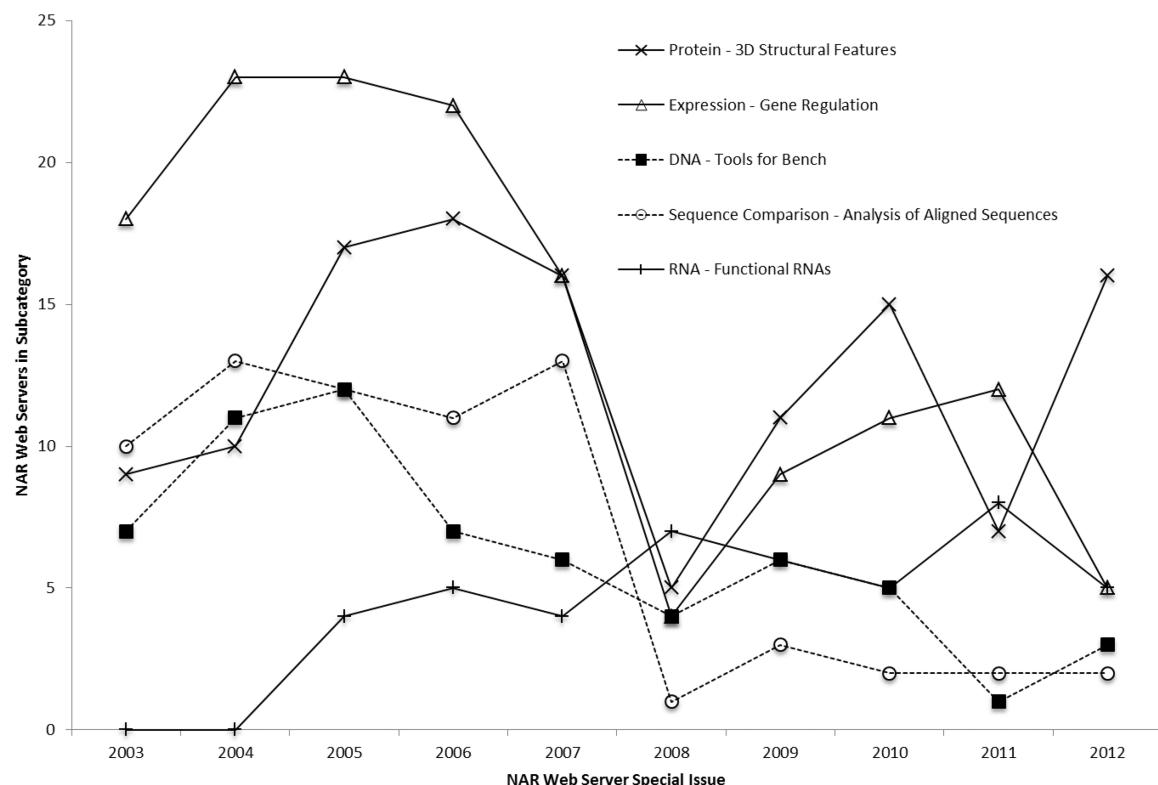


Figure 6. Number of *NAR* Web Servers from selected subcategories of the Bioinformatics Links Directory (http://bioinformatics.ca/links_directory/). The number of *NAR* Web Servers published from 2003–2012 for five selected subcategories of the Bioinformatics Links Directory: Protein: 3D Structural Features; Expression: Gene Regulation; DNA: Tools for the Bench; Sequence Comparison: Analysis of Aligned Sequences and RNA: Functional RNAs is shown.

materials being generated to support research: (i) Resource—a static resource whose intention is to convey bioinformatic information; (ii) Tool—a bioinformatic web server or downloadable software tool that can query, analyze, extract or modify input data and (iii) Database—a biological data store that can be queried. Under this new schema and with this expanded content, the Bioinformatics Links Directory now contains 1794 links comprising 455 databases, 134 resources and 1205 web server tools (Table 1). The Bioinformatics Links Directory has also initiated active curation of its content, removing dead content and correcting content errors, which has resulted in more accurate although occasionally smaller counts for 2012 (Table 1). Over time, the Bioinformatics Links Directory is expected to continue its growth and evolution in keeping with the current pace of research.

FUTURE CHALLENGES

With such a vast number of bioinformatics tools available for biological research, now more than ever, there is a need for a well-annotated and user-friendly ‘resourceome’ (1). In 2011, the Bioinformatics Links Directory introduced features to facilitate peer review of its links and link ownership (8). The application of Google +1 and other social media features, such as Twitter to the Bioinformatics Links Directory, provides users with the opportunity to share useful links; registered users may

also post comments and review a link’s usefulness or start a discussion forum. Along with enhanced search capabilities and MeSH term and keyword tagging, such a peer-review system allows users to rapidly narrow down the links most applicable to their research need. Other features added provide link owners with the capacity to edit, manage and communicate on their own link without requiring input or support from the Bioinformatics Links Directory (8).

Although necessary to remain current and to advance the utility of the Bioinformatics Links Directory, these improvements will only prove useful if driven by the community. As a community-driven repository, everyone in the research or bioinformatics community has the opportunity to help make the collection better and more meaningful. Anyone may (i) suggest a link through links@bioinformatics.ca or through the ‘Suggest a URL’ page on the Bioinformatics Links Directory; (ii) register for a free account and submit their own tool or database; (iii) rate a tool, resource or database; (iv) register for a free account and submit their review of a tool, resource or database; (v) enrich a tool or database with tutorials or user-oriented content; (vi) initiate a discussion forum on a problem related to the use of any given tool or database or (vii) share a useful tool, resource or database with their colleagues. After a decade of output from the *NAR* Web Server issues, it will be interesting to monitor the development, maturity and impact of these bioinformatics web servers and databases over the next decade.

Table 1. Historical summary of the number of resources, databases and web server tools listed in each subcategory of the Bioinformatics Links Directory between 2005 and 2012^a

Name	2011						2012 ^a						
	2005 Total	2006 Total	2007 Total	2008 Total	2009 Total	2010 Total	Resources	Databases	Tools	Total	Resources	Databases	Tools
Computer related													
Bio-* programming tools	20	20	20	20	18	18	12	18	6	12	12	18	18
C/C++	3	3	3	3	2	2	1	1	2	1	1	1	2
Databases	2	2	2	2	3	5	5	6	1	5	5	6	6
Java	4	4	4	4	4	4	3	1	4	3	1	1	4
Linux/Unix	12	12	11	11	11	10	5	4	10	5	1	4	10
PERL	5	5	5	5	5	4	1	1	5	4	1	1	5
PHP	3	3	1	1	1	1	1	1	1	1	1	1	1
Statistics	9	9	9	9	9	9	2	2	2	2	2	2	2
Web development	6	6	2	2	2	2	17	3	16	19	3	15	18
Web services	5	6	7	7	10	17	3	5	6	1	7	7	8
Workflows													
DNA													
Annotations	29	38	56	57	62	71	1	7	65	73	1	59	66
Databases													
DNA and genomic analysis	17	19	20	23	24	25	5	1	22	28	5	2	56
Gene prediction	17	32	33	34	37	37	1	1	35	37	1	1	32
Mapping and assembly	12	14	15	15	17	20	3	2	16	21	3	2	31
Phylogeny reconstruction	24	37	43	46	49	53	4	4	45	53	4	4	49
Sequence polymorphisms	22	32	39	41	42	44	1	8	39	48	1	7	47
Sequence retrieval and submission	23	26	30	32	32	30	1	6	23	30	1	7	28
Structure and sequence feature detection	71	118	142	145	150	161	3	10	150	163	3	9	149
Tools for the bench	44	55	63	65	71	76	2	7	67	76	2	4	66
Education													
Bioinformatics-related news sources	9	9	9	9	9	9	9	9	9	9	7	7	7
Community	19	19	24	23	23	18	17	2	19	17	1	1	19
Courses, programs and workshops	5	5	5	5	4	3	3	3	3	1	1	1	1
Directories and portals	12	15	15	15	15	18	12	6	18	12	1	5	18
General	15	15	14	14	14	14	13	1	14	12	1	1	13
Tutorials and directed learning resources	9	9	9	9	9	10	10	10	9	10	9	9	9
Expression													
cDNA, EST, SAGE	24	29	36	44	48	49	1	10	38	49	1	8	29
Databases													
Gene regulation	59	96	119	120	128	138	3	16	21	21	3	20	32
Gene set analysis													
Networks													
Protein expression	7	8	9	8	12	16	1	2	15	17	1	2	22
Splincing	9	16	19	19	21	22	1	3	18	22	1	2	21
Transcript expression and microarrays	54	75	89	101	108	121	5	10	107	122	5	9	110
Human genome													
Annotations	22	31	37	38	39	46	2	5	39	46	2	4	41
Databases													
Ethics	7	7	8	8	8	6	5	1	1	32	1	2	32
Genomics	4	4	3	3	10	19	3	2	15	20	3	2	5
Health and disease	11	14	19	23	27	29	1	7	23	31	1	7	21
Other resources	22	25	29	29	31	31	9	4	17	30	9	4	29
Sequence polymorphisms	17	25	33	36	38	46	2	4	43	49	2	4	50
Literature													
Databases													
Goldmines	5	6	6	6	6	5	1	4	5	1	4	5	5
Open access resources	2	2	2	2	2	3	1	3	4	1	3	4	4
Search tools	6	10	12	12	13	14	6	8	14	6	6	6	12
Text mining	7	11	15	22	30	31	4	4	30	34	4	35	39
Model organisms													
Databases													
Fish	11	11	11	11	11	11	11	6	95	94	1	94	9

(continued)

Table 1. Continued

Name	2011						2012 ^a						
	2005 Total	2006 Total	2007 Total	2008 Total	2009 Total	2010 Total	Resources	Databases	Tools	Total	Resources	Databases	Tools
Fly	12	16	17	17	21	21	8	13	23	1	7	16	24
General resources	20	23	27	28	32	32	12	16	31	3	11	16	30
Microbes	19	31	38	45	53	60	3	12	49	2	51	51	62
Mouse and rat	28	32	35	35	42	42	4	17	21	42	4	11	24
Other organisms	13	18	21	21	22	3	6	13	22	3	4	13	39
Other vertebrates	10	10	10	10	11	11	1	3	7	11	1	3	20
Plants	11	16	19	21	25	28	2	10	18	30	2	9	7
Worm	9	9	9	9	10	10	4	6	11	1	4	8	13
Yeast	11	15	18	18	21	21	2	9	10	21	2	7	12
Other molecules	5	6	6	6	7	7	1	14	7	1	1	5	5
Carbohydrates							26	26	15	1	1	15	16
Compounds									25	1	1	26	2
Databases										1	13	14	2
Enzymes										1	1	1	1
Metabolites										2	15	15	17
Peptides										2	1	1	1
Small molecules	1	3	6	6	9	13	2	13	15	15	15	15	17
Protein	29	51	58	60	63	65	1	2	103	106	1	2	56
2D Structure prediction										106	1	6	110
3D Structural features	78	53	70	75	85	100	1	6	68	75	1	6	69
3D Structure comparison										90	2	1	83
3D Structure prediction										47	3	1	86
3D Structure retrieval, viewing										58	3	8	42
Annotation and function	28	45	51	52	56	58	4	7	57	62	5	5	53
Biochemical features	26	35	44	47	53	57	5	2	43	47	2	2	117
Databases	25	37	40	41	46	46	2	2	116	1	115	2	45
Do-it-all tools for protein										117	3	11	14
Domains and motifs	6	8	8	13	14	15	3	3	12	15	3	11	14
Identification, presentation and format	50	86	112	115	121	124	14	14	115	129	14	14	109
Networks & Interactions, pathways, enzymes	48	66	88	94	107	125	1	1	113	137	1	19	123
Localization and targeting	19	30	38	38	39	41	3	3	39	42	3	3	37
Molecular dynamics and docking										44	45	1	48
Phylogeny reconstruction	28	36	44	45	53	54	4	5	47	56	4	4	49
Protein expression	7	8	8	8	10	10	1	2	7	10	1	2	8
Proteomics	21	25	27	33	37	39	3	4	32	39	3	4	26
Sequence comparison										18	18	18	33
Sequence data	7	7	8	9	9	10	1	6	3	10	1	5	9
Sequence features	14	25	31	33	38	46	2	2	46	50	2	3	47
Sequence retrieval	21	27	29	29	31	29	1	6	21	28	1	7	20
RNA										7	7	7	28
Databases										24	1	23	25
Functional RNAs	9	14	19	26	32	37	0	5	39	44	5	5	2
General resources	8	10	10	10	11	11	4	3	4	11	2	2	46
Motifs	9	19	21	22	23	25	0	1	26	27	1	1	25
Sequence retrieval, visualization and design	11	11	10	11	11	9	0	2	7	9	2	2	26
Structure prediction, visualization and design	24	38	47	54	58	62	0	3	65	68	3	3	67
Alignment editing and visualization	14	20	21	23	25	0	0	0	25	25	1	1	23
Analysis of aligned sequences	27	43	59	60	62	64	0	0	65	65	6	6	58
Comparative genomics	19	26	33	35	37	48	2	7	40	49	2	1	41
Multiple sequence alignments	19	38	50	56	57	65	1	0	67	68	1	1	46
Other alignment tools	6	11	11	11	11	12	0	0	13	13	12	12	11
Pairwise sequence alignments	11	22	23	26	33	35	1	0	34	35	30	31	31
Similarity searching	13	31	47	49	50	51	2	2	49	52	1	3	49
Total unique resources, databases and tools in Bioinformatics Links Directory	700+	1000+	1100+	1200+	1400	1500	144	480	1250	1874	455	1205	1794

^aA complete listing of all URLs listed in the Nucleic Acids Research 2012 Web Server Issue can be accessed online at: http://bioinformatics.ca/links_directory/narweb2012.

ACKNOWLEDGEMENTS

The Bioinformatics Links Directory is a community resource built on a commitment to the spirit of open access under the Attribution-Share Alike 2.5 Canada (CC BY-SA 2.5) license. The authors acknowledge the efforts of *Nucleic Acids Research* and the researchers and developers worldwide who invest considerable effort into ensuring that their research is freely accessible to all. In particular, the authors acknowledge all the contributors to the Bioinformatics Links Directory for their valuable input and suggestions for improvements to the directory; these individuals are listed on the Acknowledgements page at http://bioinformatics.ca/links_directory/acknowledgements/. In particular, they recognize the continued support of the OICR Web Development group, especially Joseph T. Yamada.

FUNDING

Ontario Institute for Cancer Research and the government of Ontario, and from Genome Canada and the Ontario Genome Institute though a platform award to the The Center of Applied Genomics (TCAG) at the Hospital for Sick Children (SickKids). Funding for open access charge: Waived by Oxford University Press.

Conflict of interest statement. None declared.

REFERENCES

- Cannata,N., Merelli,E. and Altman,R.B. (2005) Time to organize the bioinformatics resourceome. *PLoS Comput. Biol.*, **1**, e76.
- Fox,J.A., Butland,S.L., McMillan,S., Campbell,G. and Ouellette,B.F. (2005) The Bioinformatics Links Directory: a compilation of molecular biology web servers. *Nucleic Acids Res.*, **33**, W3–W24.
- Fox,J.A., McMillan,S. and Ouellette,B.F. (2006) A compilation of molecular biology web servers: 2006 update on the Bioinformatics Links Directory. *Nucleic Acids Res.*, **34**, W3–W5.
- Fox,J.A., McMillan,S. and Ouellette,B.F. (2007) Conducting research on the web: 2007 update for the bioinformatics links directory. *Nucleic Acids Res.*, **35**, W3–W5.
- Brazas,M.D., Fox,J.A., Brown,T., McMillan,S. and Ouellette,B.F. (2008) Keeping pace with the data: 2008 update on the Bioinformatics Links Directory. *Nucleic Acids Res.*, **36**, W2–W4.
- Brazas,M.D., Yamada,J.T. and Ouellette,B.F. (2009) Evolution in bioinformatic resources: 2009 update on the Bioinformatics Links Directory. *Nucleic Acids Res.*, **37**, W3–W5.
- Brazas,M.D., Yamada,J.T. and Ouellette,B.F. (2010) Providing web servers and training in Bioinformatics: 2010 update on the Bioinformatics Links Directory. *Nucleic Acids Res.*, **38**, W3–W6.
- Brazas,M.D., Yim,D.S., Yamada,J.T. and Ouellette,B.F. (2011) The 2011 Bioinformatics Links Directory update: more resources, tools and databases and features to empower the bioinformatics community. *Nucleic Acids Res.*, **39**, W3–W7.
- Google Scholar. <http://scholar.google.ca/> (10 June 2012, date last accessed).
- Google+. <http://www.google.com/+1/button/> (10 June 2012, date last accessed).